MR-based contour propagation for rectal cancer patients

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Introduction

In rectal cancer patients large day-to-day target volume deformations occur, leading to large PTV margins. The introduction of MR-guided RT with excellent soft-tissue contrast, facilitates adaptive procedures, like online re-planning with smaller margins. Time constraints demand for automatic contouring of the daily-MR. A possible fast solution is contour propagation with deformable image-registration (DIR). In rectal cancer patients DIR is challenging because of large local deformations of the CTV (meso-rectum) caused by (dis)appearing rectal and bladder content. To deal with this challenge, pre-treatment delineations can be used to define a region-of-interest (ROI) to limit DIR to the part of the anatomy, and also allows excluding regions with (dis-)appearing content. In this study, we investigate optimal parameter settings of MR-to-MR DIR, in the context of contour-propagation of the meso-rectum.

Materials and methods

Data was derived from a prospective weekly repeat-MR (3T-Philips) study containing a T2-weighted image (T2), and a T1-weighted mDixon from which four images are derived: an in-phase (IP), out-phase (OP), water (W), and a fat (F). For 5 patients a total of seventeen time points were available (3,3,3,3,5). For every time point, expert delineations of the meso-rectum (meso), rectum (rc), bladder (bl), and tumor (tm) were available. The meso was propagated both forward and backward between all possible time point combinations within each patient. After rigid registration, intensity-based B-spline DIR was performed using the `elastix` package. Total registration time was 2-3 minutes on a 3.2GHz Quad-Core Intel Xeon.

A DIR parameter-sweep was performed on the images of 2 patients (both 3 time points, 12 situations) to select the best cost-function and ROI (the resolution pyramid and optimizer were kept fixed). Three cost-functions (sum of squared differences (SSD), normalized correlation (NC), and mutual information (MI)), and 31 ROIs (entire scan (noROI), meso, meso+bl, meso+bl+tm, meso+bl+rc+tm, meso+tm+rc, meso+tm, expanded with 0,2,4,8,16mm) were evaluated. The results of the 5580 registrations were evaluated using shortest-distance-maps between the propagated meso and the manual delineation. Each distance map was summarized in a mean value (D_{mean}) indicating general performance, and the 95th percentile ($D_{95\%}$) indicative for the largest errors. These values were averaged over the two patients to assess the best parameter combination per MR image. Distance parameters were compared between rigid-only (rigid), noROI and ROI registration.

The best parameter combinations for noROI and ROI were subsequently evaluated on the remaining 3 patients (3,3,5 time points, 32 situations, 320 registrations) to assess the best image-type. Significance was tested with the Wilcoxon signed-rank test.

Results

MI was significantly better compared to NC and SSD for both $D_{95\%}$ and D_{mean}($p<0.001$). The optimal ROIs for each image-type are shown in Fig 1. The minimum and maximum $D_{95\%}$ and D_{mean} over all image-types of Rigid, noROI and optimal ROI registrations for each image type are presented in table 1.

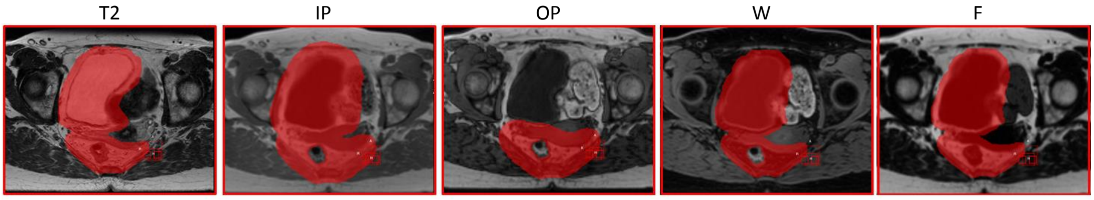

Figure 1: Example data showing optimal ROI: T2 (meso+rc+bl+tm+ 8mm), IP (meso+bl+tm+16mm), OP (meso+tm+16mm), W (meso+bl+tm+8mm), and F (meso+rc+bl+tm+8mm).

Table 1: Minimum and maximum $D_{95\%}$ and D_{mean} of all image types for rigid, noROI, and ROI registrations

	Parameter Sweep (N=12)						Evaluation (N=32)					
	$D_{95\%}$ [mm]			D_{mean}[mm]			$D_{95\%}$[mm]			D_{mean}[mm]		
	Rigid	noROI	ROI	Rigid	noROI	ROI	Rigid	noROI	ROI	Rigid	noROI	ROI
min	3.34	2.44	2.01	1.31	0.76	0.74	3.42	2.44	2.44	1.19	1.00	0.83
max	9.76	8.27	4.30	2.45	1.93	1.64	23.4	20.9	8.59	7.74	7.73	2.87

In the evaluation, the ROI registrations resulted in significantly better D_{mean} for all image-types compared to noROI registrations ($p<0.04$), and for $D_{95\%}$ only T2, OP, and F were significantly improved ($p<0.02$).

T2-image registration resulted in significantly better D_{mean} compared to other image-types ($p<10^{-5}$), for $D_{95\%}$ T2-registration was only significantly better than the OP and W images ($p<0.04$).

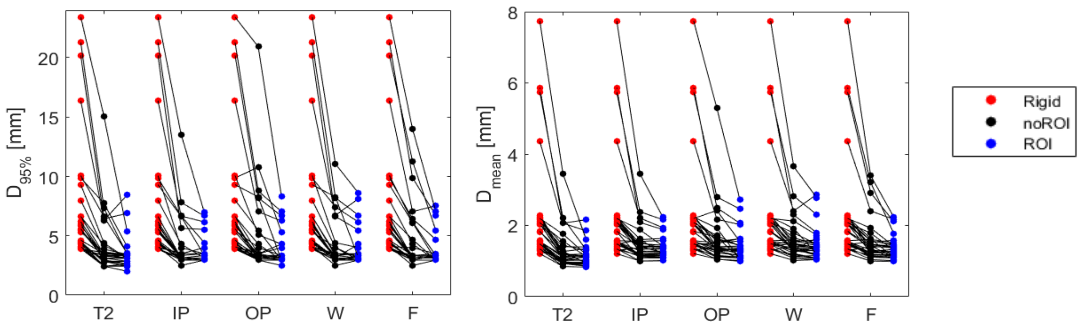

Figure 2: $D_{95\%}$(left) and D_{mean}(right) of the rigid(red), noROI(black), and ROI(blue) evaluation-registrations. Corresponding cases are connected by lines.

Conclusions

Deformable image registration can be used to propagate the meso-rectum to a daily MR in a few minutes. The use of a ROI with a margin of at least 8 mm in the DIR significantly improved the contour propagation. Especially in the cases with large initial errors, the addition of a ROI based DIR provided more accurate contours. The $D_{95\%}$ distances were initially 3.42 to 23.4 mm (rigid), and were reduced to 2.44 to 8.59 mm, which is a major step forward. Our results suggest that T2 is the best image-type, with a ROI containing mesorectum, rectum, tumor and bladder.